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Computational Simulation & Optimization of a Solar, Fuel Cell and Biomass Hybrid Energy System Using HOMER Pro Software

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Abstract

This paper shows the approach to the design aspects of a hybrid energy system that will target educational institutes. The purpose of this work is the computation, simulation & optimization of hybrid energy system. The hybrid energy system comes from the biomass gasifier generator set, solar and fuel cell with battery storage system to fulfill partially load requirement of Energy Centre, MANIT Bhopal. The computation software used for this work is HOMER Pro 3.2.3. HOMER Pro is a design simulation model that analyzed the sizing, costing optimization and control strategy of the hybrid energy system. The analysis of such hybrid energy systems feeding AC primary load of 101 kWh/day energy consumption with a 5 kW maximum load demand. The simulation results show that optimized size of components, biomass gasifier (5kW) - solar (5 kW) - fuel cell (5 kW) and optimized cost of energy about 15.064 Rs/kWh

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Keywords: Solar; Fuel cell; Biomass; Hybrid; HOMER Pro.

1. Introduction

As the fossil energy resources such as oil and natural gas will eventually be finished and the problem of pollution caused by fossil energy resources, increasing day by day, these are the main motivating factor to use renewable energy resources [1]. Renewable energy resources are not able to cover the demand every time; therefore hybrid energy systems are use [2]. A hybrid energy system generally consists of two or more than two renewable energy sources and energy storage components used together to provide increased system efficiency as well as greater balance in electrical energy supply [3].

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The purpose of this proposed work is the simulation & optimization of a Biomass gasifier generator set, standalone Solar PV & Fuel cell hybrid energy system for electrical energy supply energy centre MANIT Bhopal.
It couples a Biomass gasifier generator set, standalone Solar PV & Fuel cell hybrid energy system Battery and power conditioning unit to give different system topologies in shown in figure.1.

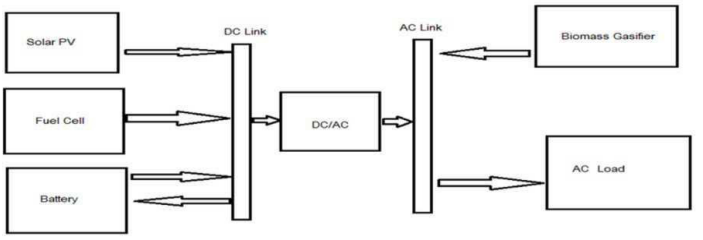


Fig. 1. Block diagram of Solar, Fuel Cell and Biomass Hybrid Energy System

2. HOMER Pro Software

The optimal sizing and costing of the components of the proposed hybrid energy system has been done using HOMER pro software (version 3.2.3). The name HOMER is an abbreviation of a Hybrid Optimization Model for Electrical Renewable and it is developed by U.S. National Renewable Energy Laboratory (NREL) [4]. HOMER Pro allows simulation of grid-connected and off-grid systems which generate electricity from various combinations of solar PV modules, wind turbines, biomass based power generators, micro-turbines, fuel cells, batteries, hydrogen storage and auxiliary generators with various fuels options and different type of loads in shown in figure.2.

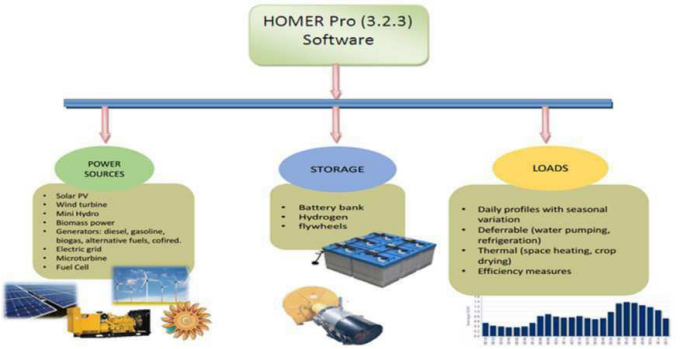


Fig. 2. Different type components of HOMER Pro software

2.1. Area of study

The selected area of educational instituted, Energy Centre, Maulana Azad National institute of Technology, Bhopal in the Indian state of Madhya Pradesh. Figure 3 show the location of the study area on the map located of 23° 12' N latitude and 77°24'E longitude.

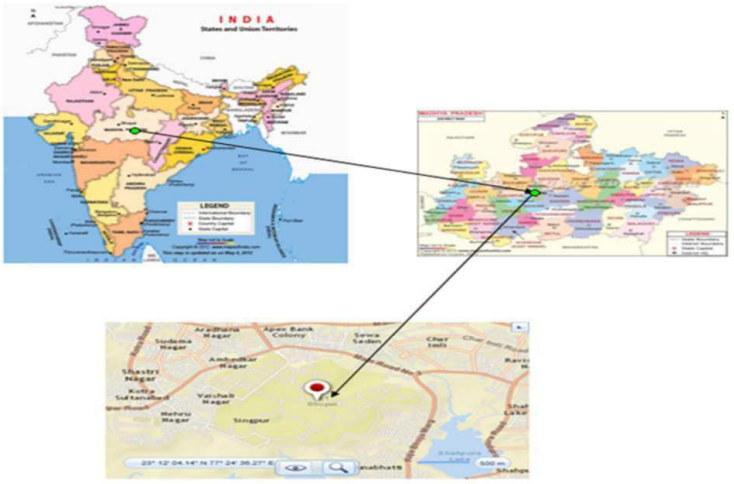


Fig. 3. Location of study area Maulana Azad National institute of Technology, Bhopal in the Indian state of Madhya Pradesh [5]

2.2. Load Profile of Study Area

Energy centre MANIT Bhopal the basic load is required to use electrical appliances like Tube light, ceiling fan, experiment setup, computer, and machinery. The energy load demands in the morning and night, hour are small. Load demand to 8 hours from 9:00 to 5:00 approximant high as compared morning and nigh hour. In this study 5 kW has been considered to scale peak load. Monthly load profile shown in figure. 4.

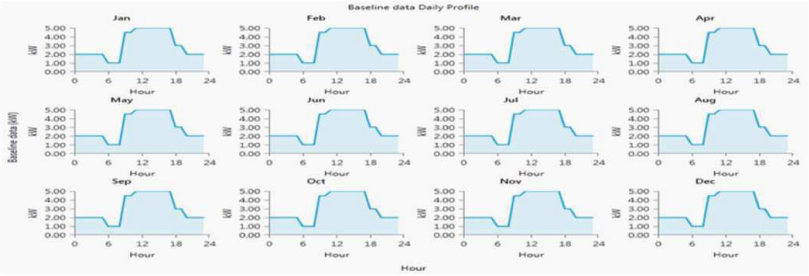


Fig. 4. Monthly load profile for Energy centre, MANIT Bhopal.

2. 3. Resources of Study Area

The selected study area solar radiation data for this region is obtained from the NASA Surface Meteorology and Solar Energy website. Discuss annual average solar radiation and temperature and biomass resources of the proposed system [6].Shown in figure.5, figure.6 and figure.7.

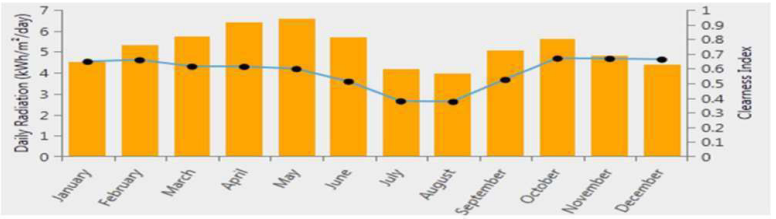


Fig. 5. Monthly global Horizontal Irradiance data of energy centre, MANIT Bhopal

Fig. 6. Monthly average temperature data of energy centre, MANIT Bhopal

Fig. 7. Monthly average available biomass data in MANIT Campus.

3. HOMER Pro Simulation Model

HOMER is an abbreviation of a Hybrid Optimization Model for Electrical Renewable [7]. This micro power optimization model simulates the operation of a system by making the energy balance calculation for a one year [8] for each hour, HOMER Pro compares the electric energy demand in the hour to the energy that the system can provide in that hour, and calculates the flows of energy to and from each element of the system. The system cost calculations account for costs such as capital, replacement, operation and maintenance, fuel, and interest. The simulation model has been designed HOMER Pro software, and consists of a biomass gasifier, Solar, Fuel Cell, battery and Electrolyzes. The schematic of this hybrid energy system model is shown in figure 8.

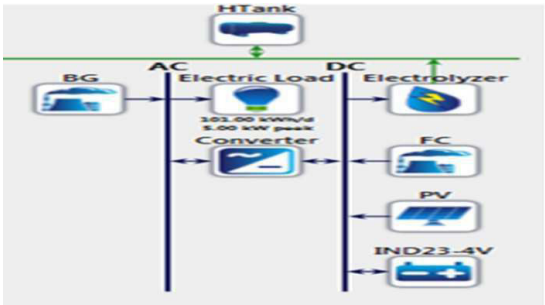


Fig.8.HOMER Simulation Model of hybrid energy system

3.1. Cost Optimization

In the cost optimization method, HOMER pro simulates each system configuration in the search space and displays the possible ones in a chart, sorted by net present cost [9]. Hence it shows a subset of these overall optimization results by displaying only the least-cost configuration within each system category or type. The cost of the hybrid energy system (C_{HES}) becomes the sum of the cost of its individual components i.e. solar PV system cost (C_{SPV}), fuel cell cost (C_{PEMFC}), biomass gasifier cost (C_{BG}), battery cost (C_{BAT}), electrolyzer cost (C_{ELECTO}), power converter cost (C_{PCON}) and hydrogen tank cost (C_{HTANK}).

$$C_{HES} = C_{SPV} + C_{FC} + C_{BG} + C_{BAT} + C_{ELECTO} + C_{PCON} + C_{HTANK} \quad (1)$$

Cost of each component of hybrid energy system,

$$C_i = N_i \times [CapC_i + (\mathrm{Re}\ C_i + NR_i) + OMC_i \quad (2)$$

Where,

i = Component of the hybrid energy system (Solar PV/fuel cell/Biomass gasifier/Power converter/Electrolyzer/Hydrogen tan

N_i= Number/Size of hybrid energy system component

$CapC_i$ =. Capital cost hybrid energy system component

ReC_i = Replacement cost hybrid energy system component

NR_i = Number of replacements

OMC_i = Operation and maintenance cost hybrid energy system component

The input information provided to HOMER Pro includes electrical loads (one year of load data), renewable energy sources, component technical details, costs, constraints, controls etc. Based on this input information and above said equations, HOMER Pro designs an optimal energy system configuration to serve the desired loads [10].

4. HOMER Simulation Results

In this section we use the HOMER simulation model to consider a Hybrid energy system of Solar Photovoltaic, Fuel Cell, Biomass gasifier generator set Battery and Electrolyser. The Main energy source Solar Photovoltaic capacity has been allowed to vary 0 to 5 kW. Fuel Cell power has been considered to change from 0 to 5 kW. Biomass gasifier generator sets 5 KW. The overall results of hybrid energy system HOMER Pro Simulation model are shown figure 9.

Fig.9.Sensitivity and optimization results from HOMER software

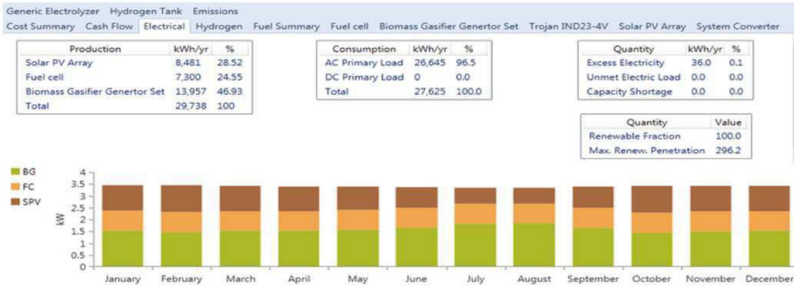
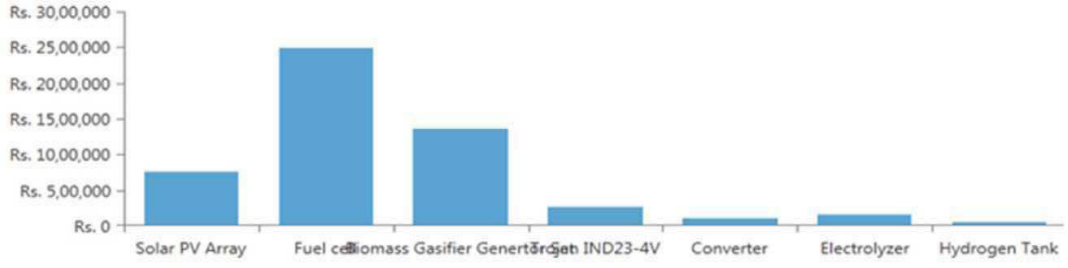


Fig.10.Electrical power production of hybrid energy system

The electrical power generated by the sources is used to feed the AC primary load. The average consumption of the AC primary load is 26645 kWh per year. The monthly average electricity production of the solar PV system, fuel cell and biomass gasifier is shown in figure 10. It can be seen that the power production of the solar PV system is 8,481 kWh/year, fuel cell power production is 7300 kWh/year and Biomass gasifier generator set power production is 13,957 kWh/year. Excess electricity is 36 kWh/year with zero percentage unmet electrical load.

The capital cost, replacement cost, O&M cost and total cost of the individual components both for one year and for a lifetime of 25 years have been shown in figure 11 from the software, the capital cost of the system is estimated at Rs 26, 81000. It is seen that the capital cost of fuel cell is higher than that of solar PV panels and represents a major share in the total capital cost of the system. The operation and maintenance cost of the fuel cell is also relatively higher. Hence it can be deduced that the inclusion of fuel cell in the system is the driving factor which decides the overall cost of the system. Also, it is seen that over the lifetime of the system, a considerable amount would be incurred in the form of replacement costs only in the case of battery replacements. The total net present cost of the system considering the capital cost and other costs incurred over the lifetime of 25 years is estimated at Rs 51, 89,003.



Component	Capital (Rs.)	Replacement (Rs.)	O&M (Rs.)	Fuel (Rs.)	Salvage (Rs.)	Total (Rs.)
Solar PV Array	Rs. 7,50,000.00	Rs. 0.00	Rs. 3,231.90	Rs. 0.00	Rs. 0.00	Rs. 7,53,232.00
Fuel cell	Rs. 10,00,000.00	Rs. 15,18,612.00	Rs. 566.23	Rs. 0.00	Rs. -23,956.00	Rs. 24,95,222.00
Biomass Gasifier Genertor Set	Rs. 4,80,000.00	Rs. 7,27,366.00	Rs. 7,287.20	Rs. 1,83,893.00	Rs. -44,119.00	Rs. 13,54,428.00
Trojan IND23-4V	Rs. 2,00,000.00	Rs. 88,262.00	Rs. 5,171.00	Rs. 0.00	Rs. -28,203.00	Rs. 2,65,230.00
Converter	Rs. 75,000.00	Rs. 21,214.00	Rs. 12,928.00	Rs. 0.00	Rs. -3,992.60	Rs. 1,05,149.00
Electrolyzer	Rs. 1,28,000.00	Rs. 42,427.00	Rs. 129.28	Rs. 0.00	Rs. -7,985.30	Rs. 1,62,571.00
Hydrogen Tank	Rs. 48,000.00	Rs. 0.00	Rs. 5,171.00	Rs. 0.00	Rs. 0.00	Rs. 53,171.00
System	Rs. 26,81,000.00	Rs. 23,97,881.00	Rs. 34,484.00	Rs. 1,83,893.00	Rs. -1,08,255.00	Rs. 51,89,003.00

Fig.11. Total net present cost of the hybrid energy system

5. Conclusion

In this paper simulation and optimization of a Biomass gasifier generator set, Solar PV & Fuel cell hybrid energy system for electrical power supply at Energy Centre MANIT Bhopal have been carried out using HOMER pro software.The cost of energy (COE) of a biomass gasifier generator set, Solar PV & Fuel cell hybrid energy system has been found to bé 15.064 Rs/kWh and total net present cost Rs.51, 89003. The excess electricity in the proposed system is found to be 36 kWh/year with zero percentage unmet electrical load. The results of the proposed system clearly validates that with the optimized sizing of 5kW Biomass gasifier generator set, 5kW solar PV, 5kW Fuel cell, the system will be able to feed the varying load requirement in all the seasons without any power interruption.

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